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The ecology and phytogeography of Mount Kinabalu pteridophytes

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Summary. The ecology, phytogeography and taxonomy of the 623 pteridophyte taxa of Mount Kinabalu are discussed in relation to each other.

Mount Kinabalu in Sabah is, at 4101 m, the highest mountain in Southeast Asia between the Himalayas and New Guinea. It encompasses an area of approximately 700 km^2 and has one of the richest floras in the world, with *c.* 4000 species of vascular plants (Beaman & Beaman 1990). Beaman & Beaman (1990) discuss some of the factors responsible for such high species diversity.

Parris *et al.* (1992) have documented the 620 pteridophyte taxa of Mount Kinabalu and give a brief introduction to their diversity and ecology. The New World species *Vittaria lineata* (L.) Sm., recorded by Christensen & Holttum (1934) and included by Parris *et al.* (1992), is omitted here, *Selaginella ciliaris* (Retz.) Spring is added on the basis of *Holttum* SFN 25370 (SING) cited by Wong (1983) and another three species have been added by Parris (1997b), bringing the total number of taxa known from the mountain to 623. Parris *et al.* (1992) point out that the collections on which the records of taxa are based were made over a period of more than a century and that it is unrealistic to expect that all taxa recorded are still there. Examination of collection data shows that 123 taxa (20% of the total) have not been gathered on Mount Kinabalu for more than 60 years. The reasons for this seem varied. Much of the low altitude forest outside the boundaries of Kinabalu Park, but included by Parris *et al.* (1992) within the area of Mount Kinabalu, has been destroyed and some taxa may have been casualties of forest clearance. The route up the south side of the mountain taken by botanists before the 1950's passed through Kiau and Lubang up to Kemburongoh, thence to Paka-paka Cave and up to the summit (Jenkins 1978); since the road to Ranau was opened all subsequent access to the mountain was from the Park Headquarters site fairly near Tenompok, joining the old route near Kemburongoh. Thus taxa not collected recently may still survive in the same sites, but are now well off the beaten track. Joseph and Mary

Clemens collected in some areas which have not been re-visited by botanists and similarly the taxa they gathered may well remain in these localities. Many pteridophyte taxa (139 or 22%) are known from one collection or one locality and of these 35 (or 6%) have not been collected for more than 60 years. Nine taxa endemic to Mount Kinabalu are known from only one collection and three of these were collected over 60 years ago.

Parris *et al.* (1992) note that the greatest number of species, 309 (to which another two can be added; Parris 1997b), has been collected at about 1500 m alt. in the lower montane forest. Data from Parris (in press) illustrate species diversity in six 0.5 hectare quadrats in the lower facies of lower montane forest on Mount Kinabalu between *c.* 1450 m and 1600 m, three of which were surveyed during December 1985 (Bukit Burong/Bukit Tupai, Liwagu River, Kiau View 1) and three of which were surveyed during May 1988 (Kiau View 2, Mempening, Silau-silau). Bukit Burong/Bukit Tupai, in ridge crest and ridge slope forest, had 72 taxa; Liwagu River, in valley forest, had 77 taxa; Kiau View, in ridge crest forest, had 93 taxa in Kiau View 1 and 84 taxa in Kiau View 2; Mempening, in ridge crest forest, had 73 taxa; Silau-silau, in valley forest, had 78 taxa. A total of 130 taxa was observed in these six quadrats. Two 0.5 hectare quadrats surveyed during August 1986 by Parris (in press) in lower montane forest between 1400 m and 1550 m in the Cameron Highlands, Peninsular Malaysia, have less pteridophyte diversity; Gunung Beremban, in ridge crest, ridge slope and valley forest, had 62 taxa, while Gunung Jasar, in ridge crest forest, had 55 taxa, with a total of 81 between the two quadrats. A 0.5 hectare quadrat surveyed during August 1987 by Parris (in press) in disturbed lower montane valley forest between 850 m and 1000 m along Wae Waule above Kanikeh, Manusela National Park, Seram, Moluccas, Indonesia, is richer than any of the Mount Kinabalu quadrats however, with a total of 96 taxa. Three 0.5 hectare quadrats surveyed during December 1985 in mixed dipterocarp forest in the Danum Valley, Ulu Segama, Sabah between 150 m and 200 m alt. (Parris in press), are of interest in that this forest type is relatively little-known on Mount Kinabalu and similar densities of taxa may apply to it. All three sites are near the Danum Valley Research Centre. The West Trail is on low broad ridges and valleys and Sungei Palum Tambun is in valley forest. The west half of West Trail had 50 taxa, while the east half of West trail had 54, with a total of 71 taxa for one hectare from the combined adjacent West Trail quadrats; Sungei Palum Tambun had 50 taxa. A total of 92 taxa were recorded for the three quadrats and another 65 are known elsewhere in the Danum (Parris 1997a). In contrast, only 97 taxa have been collected in this habitat on Mount Kinabalu.

The ecology of Mount Kinabalu pteridophytes is reviewed here in relation to taxonomy and phytogeography. The older collections made on Mount Kinabalu have rather sparse ecological data or lack them entirely. Sometimes the altitudes on the Clemens collections have been taken "with a grain of salt". Sometimes they have been ignored, for instance when the altitude given is 1200–3400 m, or when they are so improbably high they take a taxon into a vegetation zone from which it has never been recorded throughout its range. Where there are no ecological data for Mt Kinabalu collections they have been added from

material of that taxon gathered elsewhere in Sabah, or in the absence of Sabah material, from Sarawak.

The vegetation of the mountain can be divided into six altitudinally based zones. At the lowest levels on the mountain some mixed dipterocarp forest still remains (*c.* 200–700 m alt.). Above this is an upper zone (*c.* 700–1200 m) that grades into lower montane forest at its upper limits, for simplicity called "hill forest". It is useful to divide the lower montane forest into two zones, the lower facies (*c.* 1200–2100 m) which is dominated by oaks (*Lithocarpus* and *Quercus*), particularly on the ridges, and the upper facies (*c.* 2100–2600 m), where podocarps are more dominant. The upper montane forest (*c.* 2600–3500 m) contains podocarps, *Leptospermum recurvum* and *Rhododendron* species. Above the tree line is a scrub community dominated by *Leptospermum recurvum, Coprosma hookeri, Vaccinium stapfianum, Rhododendron buxifolium* and *R. ericoides*, interspersed with herb communities (Cockburn 1978). The altitudes given for the limits of the vegetation zones are approximate and relate mainly to the southern side of the mountain. The mixed dipterocarp and hill forests occur largely on Crocker Formation and Trus Madi Formation sedimentary rocks, with lower montane lower facies forest mainly on Crocker Formation and Trus Madi Formation sedimentary rocks together with Pinosuk Gravels; the lower levels of upper montane forest on the south side of the mountain are on ultramafics while the upper levels of the upper montane forest and the communities above the tree line are on adamellite (Jacobsen 1978). On other parts of the mountain extensive ultramafic intrusions occur at lower altitudes, particularly to the north-west in the Kilembun River and Penataran River region, and to the south-east in the Bambangan River and Mesilau River areas. The forest on ultramafic rocks is small-crowned and usually dominated by *Dacrydium gibbsiae* and *Leptospermum recurvum*.

Ecology and taxonomy

Thirty families of pteridophytes have been recorded from Mount Kinabalu. Table 1 summarises the number of taxa in each of the families and indicates the number of taxa in each of the six vegetation zones on the mountain, including those restricted to each vegetation zone. The largest families are Grammitidaceae, with 77 taxa, followed by Polypodiaceae (61 taxa), Hymenophyllaceae (56 taxa) and Thelypteridaceae (55 taxa).

Every fern family is best represented in the lower facies of the lower montane forest, but in the fern allies Selaginellaceae are more numerous in hill forest than in lower montane forest and Lycopodiaceae are more abundant in the upper facies of the lower montane forest. Only five families, Aspleniaceae, Dryopteridaceae, Hymenophyllaceae, Polypodiaceae and Woodsiaceae, occur throughout the six vegetation zones.

In many families which extend through several vegetation zones there is an altitudinal replacement of genera, usually with some degree of overlap. Exceptions are the

Table 1. Numbers of families in vegetation zones on Mount Kinabalu.

	No.	MDF	HF	LMF lf	LMF uf	UMF	Scrub
Fern Allies							
Equisetaceae	1	–	1	1	–	–	–
Lycopodiaceae	14	–	1	10	11	5	1
Psilotaceae	1	–	1	1	–	–	–
Selaginellaceae	17	–	12	9	–	–	–
Ferns							
Adiantaceae	11	2	7	5	1	–	–
Aspleniaceae	38	11	15	23	3	4	2
Blechnaceae	13	1	2	6	7	1	1
Cheiropleuriaceae	1	–	–	1	–	–	–
Cyatheaceae	22	2	3	18	6	4	–
Davalliaceae	13	3	6	9	1	1	–
Dennstaedtiaceae	47	2	18	37	10	3	–
Dicksoniaceae	4	1	2	3	1	–	–
Dipteridaceae	2	–	1	1	2	1	–
Dryopteridaceae	47	10	17	25	8	8	4
Gleicheniaceae	18	3	4	13	9	5	–
Grammitidaceae	77	–	5	58	34	34	7
Hymenophyllaceae	56	8	16	41	27	14	1
Lomariopsidaceae	14	1	5	9	3	2	–
Marattiaceae	7	1	2	5	–	–	–
Matoniaceae	1	–	–	1	–	–	–
Nephrolepidaceae	6	2	4	4	–	–	–
Oleandraceae	4	–	–	4	1	–	–
Ophioglossaceae	7	1	3	5	–	–	–
Plagiogyriaceae	4	–	1	2	1	3	3
Polypodiaceae	61	25	30	43	10	5	1
Pteridaceae	17	4	7	11	3	–	–
Schizaeaceae	6	2	2	3	1	1	–
Thelypteridaceae	55	11	22	42	9	1	–
Vittariaceae	16	2	9	12	2	–	–
Woodsiaceae	43	5	15	31	9	4	1
Total	623	97	211	433	159	96	21
Restricted		35	64	206	20	29	–

Abbreviations: **No.** = number of taxa; **MDF** is mixed dipterocarp forest; **HF** is hill forest; **LMF lf** is lower montane forest lower facies; **LMF uf** is lower montane forest upper facies; **UMF** is upper montane forest; **Scrub** is scrub and other communities above the tree line.

monogeneric families Equisetaceae, Psilotaceae, Selaginellaceae, Aspleniaceae, Cheiropleuriaceae, Cyatheaceae, Dipteridaceae, Matoniaceae, Nephrolepidaceae, Plagiogyriaceae and Pteridaceae. In Lycopodiaceae, for example, the largely epiphytic *Huperzia* (apart from the austral terrestrial or lithophytic *H. australiana* (Herter) Holub) occurs in hill and lower montane forest, mainly in the lower facies but sometimes reaching the lower levels of the upper facies, the terrestrial *Lycopodiella* is restricted to the lower facies of the lower montane forest, while the terrestrial *Lycopodium* grows mainly in the upper facies of the lower montane forest and in upper montane forest. In Blechnaceae the climber *Stenochlaena palustris* (Burm.f.) Bedd. is restricted to mixed dipterocarp forest and the twelve species of *Blechnum* are found in the five higher altitude vegetation zones. In Dicksoniaceae *Cystodium sorbifolium* (Sm.) J.Sm. occurs in mixed dipterocarp forest, while *Cibotium arachnoideum* (C.Chr.) Holttum and *Calochlaena javanica* (Blume) M.D.Turner & R.A.White are found in hill and lower montane lower facies forest and *Dicksonia mollis* Holttum is known from both the lower and upper facies of lower montane forest. In Dryopteridaceae *Cyclopeltis crenata* (Fée) C.Chr. is known only from mixed dipterocarp forest, the two species of *Heterogonium* are known only from mixed dipterocarp and hill forest, *Pteridrys microthecia* (Fée) C.Chr. & Ching has been found only in hill forest, the 11 species of *Tectaria* occur in mixed dipterocarp forest, hill forest and the lower parts of the lower montane forest lower facies, the four species of *Ctenitis* are restricted to hill forest and the lower parts of the lower montane forest lower facies, *Nothoperanema* is known only from the uppermost part of the lower montane forest upper facies and *Stenolepia tristis* (Blume) Alderw. occurs in upper montane forest and scrub above the tree line. In Hymenophyllaceae *Hymenophyllum peltatum* (Poir.) Desv. is found only in upper montane forest, *Nesopteris grandis* (Copel.) Copel. has only been collected in hill forest and *Microgonium* is restricted to mixed dipterocarp forest. In Lomariopsidaceae *Elaphoglossum* is a genus of lower and upper montane forest while the other genera, *Bolbitis, Lomagramma, Lomariopsis* and *Teratophyllum*, are essentially taxa of mixed dipterocarp and hill forest or only reach the lower levels of the lower facies lower montane forest. In Ophioglossaceae *Helminthostachys zeylanica* (L.) Hook. is a plant of mixed dipterocarp and hill forest while *Botrychium daucifolium* Wall. ex Hook. & Grev. occurs in lower montane forest. Several genera of Polypodiaceae occur in mixed dipterocarp to hill forest and may reach only the lower levels of the lower montane lower facies forest; they are *Aglaomorpha, Drynaria, Lecanopteris, Paragramma, Platycerium, Pyrrosia* and *Thylacopteris*. *Polypodiopteris* is the only genus of Polypodiaceae restricted to lower montane forest, where it is found in both lower and upper facies. Only three genera in the family extend to upper montane forest; they are *Belvisia, Loxogramme* and *Selliguea*. In Schizaeaceae *Lygodium* is restricted to mixed dipterocarp forest while *Schizaea* occurs in hill, lower montane and upper montane forest. In Thelypteridaceae *Amphineuron* and *Christella* are genera of mixed dipterocarp and hill forest which just reach the lower levels of lower montane lower facies forest, while *Coryphopteris* occurs in lower montane forest (but not the lowest levels of the lower facies) and upper montane forest. *Metathelypteris* has a similar distribution to *Coryphopteris*, but does not reach upper montane forest.

On Mount Kinabalu there are complex patterns of species separation within genera by geographical isolation, altitudinal replacement and habitat preference for ridge crest, ridge slope or valley forest within vegetation zones, while for epiphytes altitudinal zonation on hosts together with preferences for trunk or branch substrates provides an extra dimension. Unfortunately space precludes a discussion of this fascinating topic.

Mixed Dipterocarp Forest

The mixed dipterocarp forest of Mount Kinabalu, with 97 taxa, is not depauperate in pteridophytes, rather it is under-collected, for two reasons; most botanists seem to prefer spending time at higher levels on the mountain than in a habitat which may be perceived as very similar to that found elsewhere and thus unlikely to harbour unique plants, and because it is now rather difficult to reach this habitat except at Poring Hot Springs on the eastern side of the mountain. The Danum Valley in eastern Sabah contains a rich lowland pteridophyte flora of 157 taxa (Parris 1997a), including some interesting rheophytes such as *Antrophyum brookei* Hook. (Vittariaceae) and *Colysis fluviatilis* (Lauterb.) Ching (Polypodiaceae) which should be searched for along the lowland rivers of Mount Kinabalu. The absence of Selaginellaceae in this habitat on Mount Kinabalu is surprising, considering that nine taxa are known from the Danum Valley. Sixty-one taxa are known from the Danum Valley, but are absent from Mount Kinabalu. Many of these, e.g., *Diplazium esculentum* (Retz.) Sw. (Woodsiaceae), *Microgonium mindorense* (H.Christ) Copel. (Hymenophyllaceae) and *Microsorum linguiforme* (Mett.) Copel. (Polypodiaceae), are widespread throughout Malesia, while others, such as *Crepidomanes sarawakense* K.Iwatsuki (Hymenophyllaceae) and *Scyphularia simplicifolia* Copel. (Davalliaceae), are endemic to Borneo. Any or all of the 61 could turn up on Mount Kinabalu and boost the meagre total of 97 taxa in a potentially fern-rich habitat.

One species, *Paragramma longifolia* (Blume) T.Moore (Polypodiaceae), is known only from ultramafic substrates in mixed dipterocarp forest on Mount Kinabalu, although it is a widespread epiphyte in alluvial, mixed dipterocarp and hill forest elsewhere on various substrates.

The epiphytes of mixed dipterocarp forest are mainly members of Aspleniaceae and Polypodiaceae, some of which reach large dimensions. *Asplenium macrophyllum* Sw., *A. nidus* L. var. *curtisorum* (C.Chr.) Holttum, *Aglaomorpha drynarioides* (Hook.) Roos and *A. heraclea* (Kunze) Copel. are characteristic. The twiners *Lygodium circinnatum* (Burm.f.) Sw. and *L. microphyllum* (Cav.) R.Br. (Schizaeaceae) are restricted to this habitat. The climber *Lomagramma sinuata* C.Chr. (Lomariopsidaceae) is found here, but is not confined to mixed dipterocarp forest.

Hill forest

Hill forest supports 211 taxa, many of which extend upwards from mixed dipterocarp forest, but a number of them are also found in lower montane forest. Sixty-four taxa are restricted to this zone. Hill forest, particularly on ridge crests, may be enveloped in cloud at times and is a more regularly moist habitat than mixed dipterocarp forest in general. All but three of the pteridophyte families occur here and all of them have more taxa in hill than in mixed dipterocarp forest.

A number of taxa, *Adiantum opacum* Copel. (Adiantaceae), *Schizaea dichotoma* (L.) J.Sm. (Schizaeaceae), *Tapeinidium acuminatum* K.U.Kramer (Dennstaedtiaceae) and *Tectaria trichotoma* (Fée) Tagawa (Dryopteridaceae) are restricted to ultramafic substrates in hill forest on Mount Kinabalu, while *Huperzia phlegmaria* is found only on such substrates but in both hill and lower montane forests. *Pteris rangiferina* C.Presl ex Miq. (Pteridaceae) is largely restricted to ultramafics in hill and lower montane lower facies forests. Of these six taxa *A. opacum* appears to be a true serpentinophile and *T. trichotoma* (syn. *T. balabacensis* (H.Christ) M.G.Price) is a probable serpentinophile (Price 1987). No ecological data exist for *Tapeinidium acuminatum* apart from the Mount Kinabalu collection (Kramer 1971), but the three other species are known from non-ultramafic substrates elsewhere.

Many of the large epiphytes in Aspleniaceae and Polypodiaceae which are typical of mixed dipterocarp forest are also found in hill forest. Hymenophyllaceae, however, are more important as epiphytes in the latter than in the former zone. Climbers are more numerous than in mixed dipterocarp forest; they are *Lindsaea repens* (Bory) Thwaites var. *sessilis* (Copel.) K.U.Kramer (Dennstaedtiaceae) and *Lomagramma brooksii* Copel., *L. sinuata, Lomariopsis spectabilis* (Kunze) Mett. and *Teratophyllum clemensiae* Holttum (Dennstaedtiaceae).

Lower montane forest, lower facies

The lower facies of the lower montane forest, with 433 taxa, is the richest pteridophyte habitat on Mount Kinabalu. In addition to the 206 taxa restricted to this vegetation type a number of species considered more typical of mixed dipterocarp and hill forest reach their upper limits in the sheltered valleys of rivers and streams such as Liwagu River and Silau-silau stream, e.g., *Asplenium thunbergii* Kunze (Aspleniaceae), *Nephrolepis hirsutula* (G.Forst.) C.Presl (Nephrolepidaceae), *Colysis macrophylla* (Blume) C.Presl (Polypodiaceae) and *Christella hispidula* (Decne.) Holttum (Thelypteridaceae).

Two taxa, *Cyathea glabra* (Blume) Copel. (Cyatheaceae) and *Lindsaea jamesonioides* Baker (Dennstaedtiaceae), are restricted to ultramafic habitats in lower montane forest on Mount Kinabalu. *Oleandra tricholepis* Kunze (Oleandraceae) is largely confined to ultramafics in lower montane forest while *Pteris rangiferina* occurs mainly on ultramafics

in hill and lower montane lower facies forest. *Cyathea stipitipinnula* Holttum (Cyatheaceae), *Tapeinidium biserratum* (Blume) Alderw. (Dennstaedtiaceae), *Ctenitis atrorubens* Holttum (Dryopteridaceae) and *Sphaerostephanos lithophyllus* (Copel.) Holttum (Thelypteridaceae) are known only from ultramafic substrates in lower facies lower montane forest. *Huperzia phlegmaria*, mentioned above, is confined to ultramafic substrates in hill and lower montane forest. *Grammitis* sp. 3 (Grammitidaceae) is an epiphyte restricted to ultramafic substrates in lower montane and upper montane forest. *Schizaea fistulosa* Labill. (Schizaeaceae) is likewise restricted to ultramafic substrates in lower montane and upper montane forest. *Cyathea longipes* Copel. (Cyatheaceae) occurs mainly on ultramafics in this vegetation zone. *Cyathea stipitipinnula*, *Lindsaea jamesonioides* and *Sphaerostephanos lithophyllus* appear to be true serpentinophiles endemic to Mount Kinabalu, *Grammitis* sp. 3 is an epiphyte in ultramafic forest communities and *Ctenitis atrorubens* may be a serpentinophile (Price 1987), while *Huperzia phlegmaria, Cyathea glabra, Schizaea fistulosa* and *Tapeinidium biserratum* are found on other substrates elsewhere.

Some of the large epiphytic members of Aspleniaceae and Polypodiaceae occur in the lower facies of the lower montane forest, such as *Asplenium cymbifolium* H.Christ, *A. nidus* var. *nidus, Aglaomorpha brooksii* Copel. and *Drynaria sparsisora* (Desv.) T.Moore, but smaller epiphytes, in the families Grammitidaceae and Hymenophyllaceae, are far more numerous in this vegetation zone than at lower altitudes. The climbers *Lindsaea carvifolia* K.U.Kramer, *L. oblanceolata* Alderw., *L. repens* var. *pectinata* (Blume) Mett. ex Kuhn, *L. repens* var. *pseudohemiptera* Alderw. and *L. repens* var. *sessilis* (Dennstaedtiaceae) and *Lomagramma brooksii* and *Teratophyllum clemensiae* (Lomariopsidaceae) are found here.

Lower montane forest, upper facies

The upper facies of the lower montane forest has 159 taxa, fewer than hill forest. Many of the taxa occur in the lower facies of the lower montane forest and/or the upper montane forest and only 20 (13%) are restricted to this vegetation zone. Eight families found in vegetation zones at lower altitudes including the lower facies of lower montane forest do not reach the upper facies.

In the upper facies of the lower montane forest *Blechnum* sp. 1 (Blechnaceae), *Cyathea discophora* Holttum (Cyatheaceae) and *Sphaerostephanos lobangensis* (C.Chr.) Holttum (Thelypteridaceae) are apparently true serpentinophiles which are restricted to ultramafics and are endemic to Mount Kinabalu.

Large epiphytes and climbers characteristic of the lower vegetation zones are absent from the upper facies of lower montane forest. Two families, Grammitidaceae and Hymenophyllaceae, provide most of the epiphytes in this vegetation zone and the two above it.

Upper montane forest

Compared with the upper facies of the lower montane forest, the upper montane forest has fewer taxa (96) with a higher proportion (29 taxa, i.e., 30%) restricted to it. Four families which occur up to and including the upper facies of lower montane forest do not reach the upper montane forest. Most families have fewer taxa in this vegetation zone than in the upper facies of the lower montane forest, apart from Aspleniaceae, which has one more, and Grammitidaceae, which has the same number.

Two taxa, *Cyathea havilandii* Baker (Cyatheaceae) and *Xiphopteris nudicarpa* (P.M.Zamora & Co) Parris (Grammitidaceae) are found only on ultramafic substrates in upper montane forest. *Grammitis* sp. 3 is epiphytic on ultramafic substrates in lower montane and upper montane forest and *Schizaea fistulosa* occurs on ultramafic substrates in lower montane and upper montane forest. Both were discussed previously under lower montane forest. *Cyathea havilandii* appears to be a true serpentinophile and is endemic to Mount Kinabalu. *Xiphopteris nudicarpa* may also be a serpentinophile. It is known elsewhere only from southern Palawan, Philippines, where there are ultramafic deposits.

Scrub above tree line

The 21 taxa found above the tree line do not include any restricted to this habitat. Rather they are species of upper montane forest such as *Grammitis clemensiae* (Copel.) Parris (Grammitidaceae) and *Athyrium clemensiae* Copel. (Woodsiaceae) or are wide ranging at lower altitudes, sometimes reaching the lower facies of the lower montane forest, e.g., *Asplenium elmeri* H.Christ (Aspleniaceae) and *Plagiogyria clemensiae* Copel. (Plagiogyriaceae). Ultramafic substrates do not occur in this vegetation zone.

Ecology and phytogeography

The pteridophyte flora of Mount Kinabalu can be divided into 13 distribution patterns, which are the same as those delimited by Parris (1993) with the removal of Regional endemics and the addition of Borneo endemics, Sabah endemics and Mount Kinabalu endemics.

The distribution patterns are: 1, Old World and New World; 2, Old World (South-east Asia and often the Pacific Islands, extending either to mainland Africa or to Madagascar and the Mascarene Islands off the east coast of Africa); 3, South-east Asia-Malesia-Pacific (Malesia together with South-east Asia from Sri Lanka to China and the Pacific at least to Australia or the Solomon Islands, sometimes to New Zealand, the Hawaiian Islands or Marquesas Islands); 4, Malesia-Pacific (as 3 without South-east Asia); 5, South-east Asia-Malesia (as

Table 2. Numbers of taxa in each vegetation zone on Mount Kinabalu arranged in distribution patterns.

Phytogeographical element	No.	MDF	HF	LMF	LMF	UMF	Scrub
1 Old World & New World	14	2	5	10	4	4	–
2 Old World	34	13	17	22	7	3	–
3 SE Asia-Malesia–Pacific	90	25	48	61	22	7	1
4 Malesia–Pacific	37	7	13	25	12	7	1
5 SE Asia–Malesia	85	17	32	63	19	7	–
6 Malesia-wide	109	8	23	75	35	30	9
7 SE Asia–West Malesia	48	11	16	31	8	6	2
8 West Malesia	67	6	19	48	11	5	–
9 Austral	3	–	–	–	2	3	2
10 Borneo endemics	72	5	31	55	13	6	1
11 Sabah endemics	14	2	2	10	4	2	–
12 Mount Kinabalu endemics	49	–	3	33	22	16	5
13 Adventives	1	1	1	–	–	–	–
Total	623	97	211	433	159	96	21

Abbreviations: as in Table 1.

3 without the Pacific); 6, Malesia-wide (or at least across Zollinger's Line, which includes the Lesser Sunda Islands with West Malesia, rather than Wallace's Line which splits the Lesser Sunda Islands between Bali and Lombok); 7, South-east Asia-West Malesia (not across Zollinger's Line); 8, West Malesia; 9, Austral (New Guinea, Australia and New Zealand affinities); 10, Borneo endemics; 11, Sabah endemics; 12, Mount Kinabalu endemics; 13, adventives.

Table 2 gives the number of taxa in each distribution pattern in each vegetation zone and shows several interesting features. As might be expected from the great preponderance of taxa in the lower facies of the lower montane forest, most taxa of each element are found there. The Mount Kinabalu endemic taxa are well represented in upper montane forest and their importance in this zone is only exceeded by the Malesia-wide pattern. Holttum (1978) notes that in general the ferns up to 3000 feet (*c.* 900 m alt., hill forest) are also found in Peninsular Malaysia and Sumatra, with many also in the Philippines. A total of 308 taxa occur in the mixed dipterocarp and hill forests up to approximately 1200 m on Mount Kinabalu, of which 86% have the distribution mentioned by Holttum or are more wide-ranging (i.e., have distribution patterns of types 1 to 9). Holttum (1978) says that above 3000 feet a considerable proportion of the species have more restricted distributions, many being confined to Borneo, but this is not borne out by Table 2 where it can be seen that relatively wide-ranging taxa (of distribution patterns 1 to 9) occur in all vegetation zones up

Table 3. Families of Mount Kinabalu pteridophytes arranged in distribution patterns.

		Phytogeographical elements												
	No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Fern allies														
Equisetacea	1	–	–	1	–	–	–	–	–	–	–	–	–	–
Lycopodiaceae	14	3	2	2	1	3	1	–	–	2	–	–	–	–
Psilotaceae	1	1	–	–	–	–	–	–	–	–	–	–	–	–
Selaginellaceae	17	–	–	1	–	4	–	1	–	–	9	1	1	–
Ferns														
Adiantaceae	11	–	–	4	1	1	2	1	1	–	–	–	–	1
Aspleniaceae	38	–	7	3	4	5	7	4	2	–	2	3	1	–
Blechnaceae	13	–	–	4	1	1	1	–	2	1	–	1	2	–
Cheiropleuriaceae	1	–	–	–	–	1	–	–	–	–	–	–	–	–
Cyatheaceae	22	–	–	–	–	1	3	2	6	–	4	–	6	–
Davalliaceae	13	–	2	3	–	1	1	2	–	–	4	–	–	–
Dennstaedtiaceae	47	1	2	6	5	10	5	5	10	–	1	–	2	–
Dicksoniaceae	4	–	–	–	–	–	3	–	1	–	–	–	–	–
Dipteridaceae	2	–	–	1	–	–	1	–	–	–	–	–	–	–
Dryopteridaceae	47	2	–	7	2	6	11	6	4	–	2	3	4	–
Gleicheniaceae	18	–	–	3	1	2	6	2	1	–	2	1	–	–
Grammitidaceae	77	–	–	8	6	12	21	2	6	–	10	–	12	–
Hymenophyllaceae	56	1	5	10	4	9	15	3	6	–	2	–	1	–
Lomariopsidaceae	14	–	1	1	2	3	5	1	–	–	1	–	–	–
Marattiaceae	7	–	–	2	–	–	1	–	1	–	3	–	–	–
Matoniaceae	1	–	–	–	–	–	1	–	–	–	–	–	–	–
Nephrolepidaceae	6	1	1	2	–	2	–	–	–	–	–	–	–	–
Oleandraceae	4	–	–	–	1	–	–	1	–	–	1	1	–	–
Ophioglossaceae	7	2	1	2	1	–	–	–	1	–	–	–	–	–
Plagiogyriaceae	4	–	–	1	–	–	–	2	–	–	1	–	–	–
Polypodiaceae	61	–	4	9	3	9	6	8	8	–	10	1	3	–
Pteridaceae	17	1	2	4	–	2	2	1	1	–	–	2	2	–
Schizaeaceae	6	1	2	2	1	–	–	–	–	–	–	–	–	–
Thelypteridaceae	55	1	2	5	3	5	10	4	6	–	11	–	8	–
Vittariaceae	16	–	2	6	1	2	2	1	2	–	–	–	–	–
Woodsiaceae	43	–	1	3	–	6	5	2	9	–	9	1	7	–
Total	623	14	34	90	37	85	109	48	67	3	72	14	49	

Phytogeographical elements: **1**, Old World & New World; **2**, Old World; **3**, SE Asia–Malesia–Pacific; **4**, Malesia–Pacific; **5**, SE Asia–Malesia; **6**, Malesia-wide; **7**, SE Asia–West Malesia; **8**, West Malesia; **9**, Austral; **10**, Borneo endemics; **11**, Sabah endemics; **12**, Mount Kinabalu endemics; **13**, adventives.

to and including upper montane forest and scrub. Taxa of distribution patterns 1-9 constitute 77% of lower montane forest lower facies taxa, 75% of lower montane upper facies and upper montane forest taxa and 71% of scrub taxa. The most important distribution pattern in lower montane forest, both lower and upper facies, upper montane forest and scrub is Malesia-wide. As Holttum (1978) points out, a few of the high altitude ferns have relatives in north temperate regions. These are the species of *Athyrium*, a genus not well represented in the tropics, although several species are known from elsewhere in Malesia.

Phytogeography and taxonomy

Table 3 shows the families of pteridophytes on Mount Kinabalu arranged in phytogeographical distribution patterns. No one distribution pattern includes all families and no family is represented in all distribution patterns. Grammitidaceae are the most numerous in the largest number of patterns, Malesia–Pacific, South-east Asia–Malesia, Malesia-wide, Borneo endemic and Mount Kinabalu endemics, as might be expected from the largest family on Mount Kinabalu. It is pleasing to note that the one adventive species, *Pityrogramma calomelanos* (L.) Link (Adiantaceae) is only found in disturbed areas and is very unlikely to have any ecological impact on Mount Kinabalu.

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